DOCUMENT RESUME

ED 287 706 SE 048 662

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TITLE A Constructivist View of Learning and Teaching in Science. Children's Learning in Science Project.
INSTITUTION Leeds Univ. (England). Centre for Studies in Science and Mathematics Education.
PUB DATE Jun 87
NOTE 31p.; Document contains small type which may not reproduce well. For related publications, see SE 048 661-665.
AVAILABLE FROM Children's Learning in Science Project, Centre for Studies in Science and Mathematics Education, The University of Leeds, Leeds LS2 9JT England, United Kingdom.
PUB TYPE Reports - Descriptive (141) -- Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Classroom Communication; Concept Formation; *Elementary School Science; Elementary Secondary Education; Foreign Countries; Instructional Improvement; Learning Strategies; *Learning Theories; *Process Education; Science Curriculum; Science Education; *Science Instruction; Scientific Concepts; Scientific Literacy; *Secondary School Science; Teaching Methods
IDENTIFIERS Childrens Learning in Science Project; *Constructivism; United Kingdom

ABSTRACT

During the period 1984-1986, over 30 teachers from the Yorkshire (England) region have worked in collaboration with the Children's Learning in Science Project (CLIS) developing and testing teaching schemes in the areas of energy, particle theory, and plant nutrition. The project is based upon the constructivist approach to teaching. This booklet was designed to provide teachers with a better understanding of constructivism, particularly as it applies to teaching science. It contains sections on: (1) learning and teaching (including various views of learning theory); and (2) a constructivist view of learning (containing information on learning processes, constructivist teaching techniques, and some implications for constructivism on various aspects of education). Also included are a list of references and sources for further reading on the topic. (TW)

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CLIS IN THE CLASSROOM

CHILDREN'S LEARNING IN SCIENCE PROJECT

A constructivist view of learning and teaching in science

Philip Scott
in association with
Tony Dyson
Steven Gater

U.S. DEPARTMENT OF EDUCATION
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Children's Learning in Science Project

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Philip Scott
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June 1987

Centre for Studies in Science and Mathematics Education
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Acknowledgements

All members of the project team have had some part to play in the development of the work described here. Particular thanks are due to Sharon Crossley and Elisabeth Stephens for their patience and good humour through many redrafts.

We would also like to express our appreciation to the Headteachers, staff and students of all schools involved in the trialling of materials and to our local education authorities for their support of our involvement with this project; without their co-operation and help the work would not have been possible.

Finally, we would like to thank members of the Steering Committee and others for their helpful comments on the draft.

Preface

During the last three years over thirty science teachers from the Yorkshire region have worked in collaboration with the Children's Learning in Science Project, developing and trialling teaching schemes in the areas of energy, particle theory and plant nutrition.

It was felt that it would be useful to have a series of booklets written by teachers for teachers to present the theoretical rationale which underlies the schemes and also to provide practical advice for those taking up a constructivist approach to teaching.

A series of booklets has been planned and edited by P. Scott and R. Senior. The first two in the series are:

Booklet 1: A constructivist view of learning and teaching in science. P. Scott.

Booklet 2: Teaching strategies for developing understanding in science. R. Needham.

The booklets provide guidance on using the teaching schemes and should be read in conjunction with them. We hope that they will prove to be both interesting and helpful.

1 Learning and teaching

1.1 An introduction

A class of mixed ability thirteen year olds, in a comprehensive school, was introduced to the concept of gravitational force. Prior to teaching, the teacher posed the following two questions:

1. You drop a ball from your hand. It falls. WHY?

2. You are standing on the surface of the Moon. You drop a ball. What happens? WHY?

The class was divided into small groups to discuss their ideas relating to each of these questions. They were also asked to record any conclusions which were reached.

In response to question 1, some pupils found it difficult to see that there was an issue worthy of further explanation. Thus their answers were of the form:

"Because we let go of it."

Another group offered:

"Ball drops because it has no engines or power to keep it up like an aeroplane."

In a number of cases the air/atmosphere was seen as being instrumental in making the ball fall:

"Ball falls because of the air."

Other pupils obviously 'knew' about gravity:

"Ball falls because of gravity."

"The ball drops because the gravity is pushing the ball down and because of the weight."

The latter response refers to gravity as 'pushing' and uses the term 'weight' in a way which is unlikely to be according to scientific definition. Another group stated:

"It is the gravity that makes it fall because the air is pushing the ball down."

This extract reveals that the confident usage of words such as 'gravity' by the child may well be based upon an unconventional and unexpected interpretation. Simply mentioning the 'key word' provides no insight into level of real understanding.

A similar variation in viewpoints was evident in response to the second question, but one theme did recur:

"The ball will float away."

"The ball will float away into space because there is no gravity."

"It floated because its not gravity."

One group attempted to relate their answer to the part played by the atmosphere:

"The ball floats away into space. No oxygen to pull it down cos no atmosphere."

Another group of pupils managed to bring a smile to the teacher's face with:

"The ball drops very slowly because the gravity on the moon is much less than on the earth."

The collection of this information took twenty minutes in class and the pupils enjoyed the exercise. It was the first time that the teacher had used such a strategy, and in later discussion she commented:

> "I usually just get straight on with the teaching. I was amazed by the range of ideas that the pupils came up with - I'd never even before thought about mentioning 'the air' in teaching gravity."

1.2 Views of learning

An interesting start to the work on gravity .... but what next? How a teacher approaches the teaching of this or any other topic will depend, in part, upon their view of how pupils learn. Teachers' views or theories of learning are not often made explicit - staffroom discussions, or even departmental meetings, rarely focus upon the issue of 'how pupils learn'. Yet over the last two decades there has been a considerable amount of research undertaken by cognitive psychologists and science educators which addresses just this problem. The key idea behind this body of research is that learning is an active process and that knowledge must be constructed by the learner. (In the example just [illegible]e have seen some pupils explaining free fall as being due to t[illegible] - an idea which is quite common and illustrates a link which pupils have made for themselves.) This contemporary constructivist view of learning has important and basic implications for classroom teaching. This booklet describes the main features of this view and outlines some of its implications for the teaching of science.

Whatever view of learning is adopted by the teacher, constructivist or other, it will have practical implications for what goes on in the classroom. This point is illustrated in the next section.

1.3 A view of learning ... in practice

Although teachers may not discuss views of learning very often, their decisions and actions in the classroom may well be guided by their own implicit views. Working theories such as:

- pupils' understanding of new ideas can be improved through 'plenty of practice'

- practical work is important in providing pupils with concrete examples of new phenomena

may form part of a teacher's personal view of learning.

An underlying feature of a particular view of learning, which can be seen to be implicit in some science teaching in secondary schools, has been described by Barnes (1976) as a 'transmission view'. (Discussion of other views of learning can be found elsewhere e.g. Watts, 1984.) He describes the teacher who adopts this view as operating a 'speaking tube' down which he/she sends knowledge. When the teacher asks questions of pupils or tells them to write, Barnes considers that it is primarily in order to test whether they have in fact received the knowledge transmitted by the teacher.

A tacit assumption being made here by the teacher, is that the pupils do not bring relevant ideas of their own to lessons and that they act simply as recipients of knowledge adding information to their 'memory store'. Thus, during teaching, chunks of information are transferred from teacher to pupil:

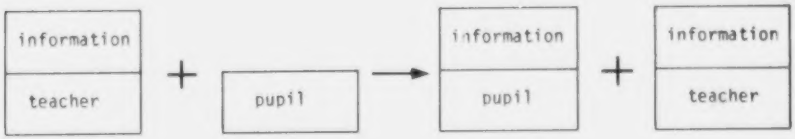


Figure 1. A transmission view of learning

This view is reflected in a variety of different ways: through the teacher's approach to the curriculum, in the type of teaching strategies adopted by the teachers and in the way pupils are assessed.

From the 'transmission view' of learning the curriculum is seen as the list of things to be taught. The emphasis is upon the information and skills to be transferred. Science is thus presented as a catalogue of 'facts' and discussions in school science departments can reflect members' concern over particular parts of this catalogue.

"No! We can't leave block and tackles out!"

"But we've always done separating salt and sand in the first year!"

If a transmission view of learning is adopted then perhaps the most efficient way of imparting knowledge to a class of pupils is to tell them what they need to know. The emphasis is thus upon 'closed' teaching strategies which support the flow of information from teacher to pupils. Practical work may be included in order to help motivate pupils and it is often concerned with the demonstration of established theory. Thus pupils are guided by instructions or worksheets to 'notice' certain features and these are seen to be interpreted in one way only. Interactions between the teacher and pupils in the class can also have the same characteristics with the teacher asking a series of closed questions and pupils playing the game of 'guess what teacher is thinking'.

Teacher	Do you remember the electric bell?
Pupil 1	Yes.
Teacher	Did any of you notice, did any of you actually hold on to the bell after it had been working? What did you notice?
Pupil 1	Vibration.
Teacher	Well, the arm vibrated, yes. Sound. What else did you notice?
Pupil 2	It was moving.
Teacher	That's not quite what I'm getting at ...
Pupil 3	There were sparks there.
Teacher	Heat. Did you notice some heat?

Pupil 2 There were sparks from there.

Teacher There were?

Pupil 2 Sparks. I don't know about ...

Teacher There were some sparks, yes. Let's just ignore the sparks a minute, but we can come back to those. Some heat. There was a little bit of heat there with that one.

Evaluation of learning emphasises summative assessment; knowledge has either been transferred or it has not! Any remedial action by the teacher, in the face of incorrect answers, may be limited to a review of test performance.

From this brief description readers may recognise some aspects of the transmission view as reflecting what they have actually witnessed in schools. Certainly, if a teacher adopts this view of learning then his/her teaching will display such features. For instance, the teacher may not regard children's pre-existing ideas as being important. Thus, with reference to the opening passage about gravity, the teacher might ask the pupils about their ideas relating to 'why things fall' but probably would not attach any particular significance to their arguments about 'the role of the air'. The teacher may be genuinely interested in what the pupils have to say but would most likely regard such an exercise as being an unconnected preliminary to the real business of teaching.

Pupils' ideas, if they differed from what was to be taught, would simply be supplanted. The teacher is seen as being the active transmitter of knowledge. The pupil is initially empty-headed and plays an intellectually passive role in adopting that knowledge (although the pupil may appear far from passive in class!).

This perspective differs in fundamental ways from contemporary views of learning which are outlined in the next section.

2 A constructivist view of learning

2.1 The learning process

A constructivist view of learning perceives students as active learners who come to science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences. Learning science, therefore, involves students in not only adopting new ideas, but also in modifying or abandoning their pre-existing ones. Such a process is one in which learners actively make sense of the world by constructing meanings.

There are a number of key points in this view which are summarised here (for a more detailed account see Driver and Bell, 1985):

1. Learning outcomes depend not only on the learning environment but also on the prior knowledge, attitudes and goals of the learner.
   WHAT IS ALREADY IN THE LEARNER'S MIND MATTERS

2. Learning involves the construction of knowledge through experience with the physical environment and through social interaction.
   INDIVIDUALS CONSTRUCT THEIR OWN MEANING

3. Constructing links with prior knowledge is an active process involving the generation, checking and restructuring of ideas or hypotheses.
   THE CONSTRUCTION OF MEANING IS A CONTINUOUS AND ACTIVE PROCESS

4. Learning science is not simply a matter of adding to and extending existing concepts, but may involve their radical re-organisation.
   LEARNING MAY INVOLVE CONCEPTUAL CHANGE

5. Meanings, once constructed, can be accepted or rejected.
   THE CONSTRUCTION OF MEANING DOES NOT ALWAYS LEAD TO BELIEF

6. Learning is not passive. Individuals are purposive beings who set their own goals and control their own learning.
   LEARNERS HAVE THE FINAL RESPONSIBILITY FOR THEIR LEARNING

7. Students frequently bring similar ideas, about natural phenomena, to the classroom. This is hardly surprising when one considers the extent of their shared experiences - school life, hobbies, clubs, television, magazines, music etc.
   SOME CONSTRUCTED MEANINGS ARE SHARED

A considerable amount of research has been carried out into the kinds of ideas which students bring to science lessons. Areas which have been investigated include those of circuit electricity, gravity, dynamics, heat, light, plant nutrition, particulate theory and energy. Studies in various parts of the world have shown, for example, that many secondary school students have an informal theory of motion which includes the idea that 'a steady force is needed for steady motion'. Such a theory makes good sense in the everyday world of frictional forces and as such may be strongly held onto by the student - 'if it works for me, why should I give it up?'. A problem lies in the fact that students do not always consider their own ideas in such an explicit way. This can lead to a situation where existing student ideas challenge the explanations of accepted science (in this case Newtonian mechanics) - without either the student or the teacher being aware of the 'debate'.

In order to respond to these kinds of problems, the Children's Learning in Science Project has developed teaching schemes which acknowledge and start from students' existing ideas. (For a description of the development of the schemes, see Driver and Oldham, 1986). The general outline for the teaching sequences is shown in Figure 2.

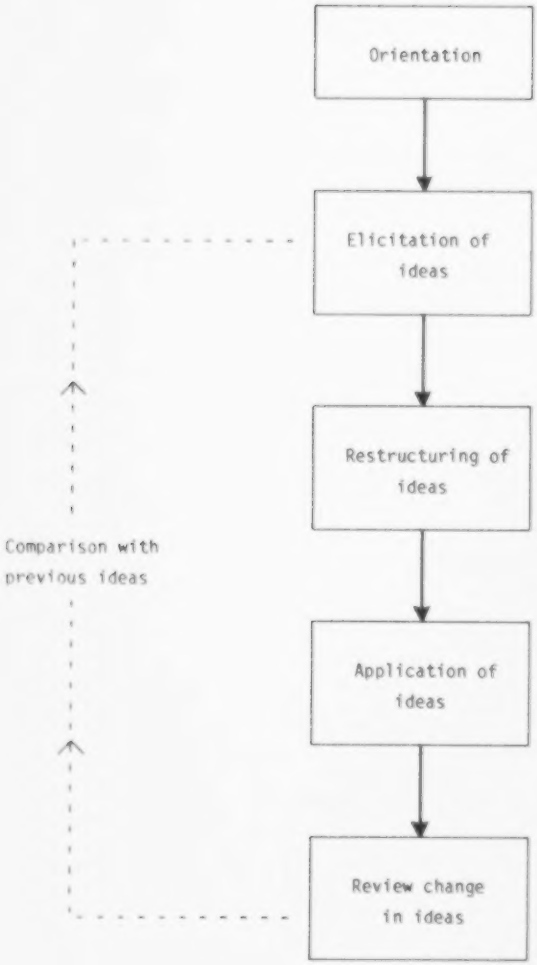


Figure 2. A generalised model for a Constructivist Teaching Sequence.

Teachers working with the project have used this model as a framework in developing experimental schemes for the teaching of Particle Theory, Plant Nutrition and Energy. (An outline of the rationale for the development of the schemes is given in Driver and Oldham, 1986.)

2.2 Constructivist teaching

The adoption of a constructivist view of learning necessarily has fundamental implications for classroom/laboratory activity. Some of these implications are now explored with reference to the sequence illustrated in figure 2.

i) Elicitation of ideas

The teaching commences with orientation. This really sets the scene for the work to come in introducing the context of study - and hopefully raising interest in what is to follow.

The constructivist view recognises that pupils have their own prior knowledge, ideas, theories. Elicitation of these ideas at the beginning of a lesson sequence is important for two reasons:

1. If the pupil is to develop his/her existing ideas relating to a particular phenomenon then it is important that those ideas should be explicitly considered by the pupil. Each pupil needs to be aware of his/her own starting point in the learning process (that air makes things fall, perhaps).

2. The teacher needs to know what the pupils think in order that further teaching strategies can be planned from that starting point. In case studies of classroom learning we have frequently observed a mismatch between what the student thinks and what the teacher thinks the student thinks (see Bell, 1985). A mismatch which may well have resulted from the teacher's lack of awareness of the kinds of pre-existing ideas which the pupil is bringing to the lesson - or indeed the teacher's tacit assumption that the student has no pre-existing ideas at all (or none worth considering as a basis for further learning). We have also

witnessed apparently obscure contributions from pupils being overlooked or dismissed on the grounds of irrelevance. Irrelevant to the focussed perspective of the teacher maybe - but not to the student and possibly not to the problem. The teacher needs to be aware of what the pupils think (that air makes things fall ... and not a mysterious, invisible force whose effects can be felt over large distances), but finding this out is not always easy.

How does a single teacher elicit the individual views of thirty pupils in one hour slots of time scattered over a week? In order to do this teachers working with the project have reviewed their teaching methods. Brainstorming sessions, small group discussion work, circuses of practical activities, questionnaires and individual projects are now more frequently used than teacher presentations and note copying. Whereas before, discussion amongst pupils was regarded by the teacher as being potentially disruptive - it is now positively encouraged. The teacher moves away from asking closed questions towards an open-ended situation in which pupils are encouraged to express their individual viewpoints. Wall posters, prepared by the pupils, are used to display pupil ideas. The posters act as a paper memory holding and making explicit the initial ideas of the pupil - a reference point against which any development of ideas can be judged. The very presence of the posters on the wall also indicates that the teacher is paying more than lip-service to the ideas which pupils have brought to the lesson.

The elicitation of pupil ideas may worry some teachers. A recurring question is:

> "If all of the children say what they think won't this be potentially confusing? - They might remember the wrong idea."

Our experience would suggest that pupils are prepared to modify/change their working ideas as they respond, for instance, to a circus of activities which they are asked to explain, in their own terms. Nevertheless, there are some ideas which appear to be more deep seated and which tend to persist in pupils' thinking.

Examples of such ideas would include:

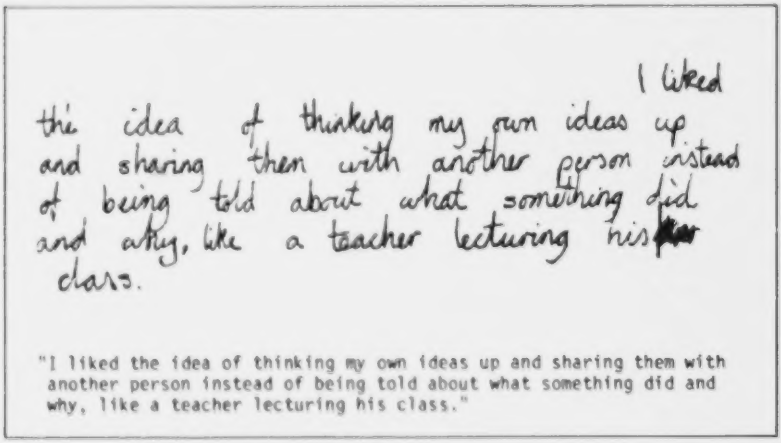
"Plants get their food from the soil."

"Energy gets used up when a job is done."

"A steady force is needed to produce a steady motion."

These are very commonly held notions, both amongst adults and children. It would seem unlikely that such ideas can be successfully challenged until their existence is recognised and made explicit by the learner. Many pupils experience difficulties in developing new concepts and in doing so cannot, and are not encouraged to, even identify where their difficulties lie. An understanding of dynamics would be severely undermined by the existence of the 'steady force - steady motion' idea. If this is ignored then the learning process will appear straightforward to the teacher (pupil as empty vessel ready for filling) but almost certainly problematical to the pupil.

Diary extracts from pupils involved in the experimental teaching sequences would suggest that they do enjoy making clear their own ideas:


I liked
the idea of thinking my own ideas up
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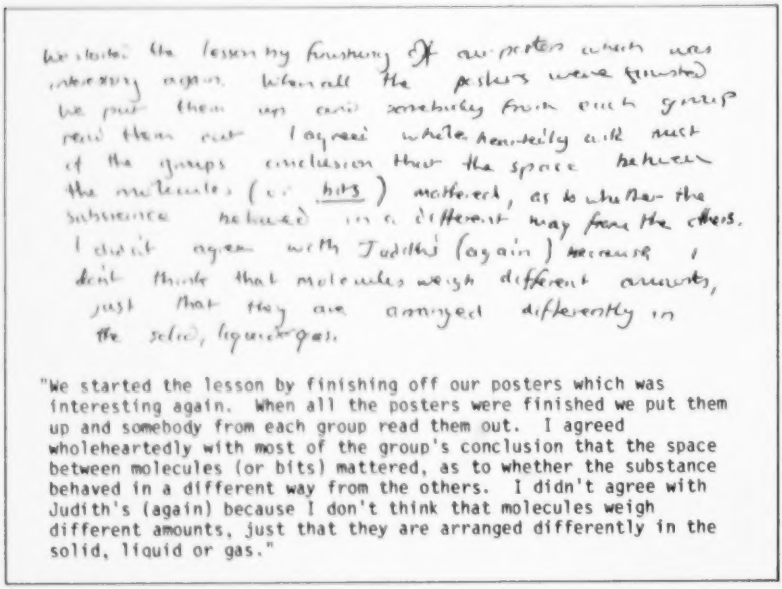
class.

"I liked the idea of thinking my own ideas up and sharing them with another person instead of being told about what something did and why, like a teacher lecturing his class."

ii) Restructuring and application of ideas

Bringing pupil ideas out into the open does not represent the endpoint of the constructivist teaching sequence. Indeed it is only the beginning. Within any single class the range of pupil ideas elicited is likely to be wide and inevitably there will be divergence between pupil views and the accepted view of the science community. The restructuring phase, therefore, is a crucial one in which the pupils consider the variety of ideas which have emerged and are helped to develop their viewpoints towards that of the currently accepted scientific theory. It must be remembered that restructuring of ideas is the responsibility of the learner. The teacher can specify appropriate activities designed to promote restructuring but cannot 'do the learning for the child'. Appropriate activities, in the first instance, may involve exchange of ideas amongst pupils. This exchange of views may lead to disagreement among pupils and to the challenging of particular perspectives.

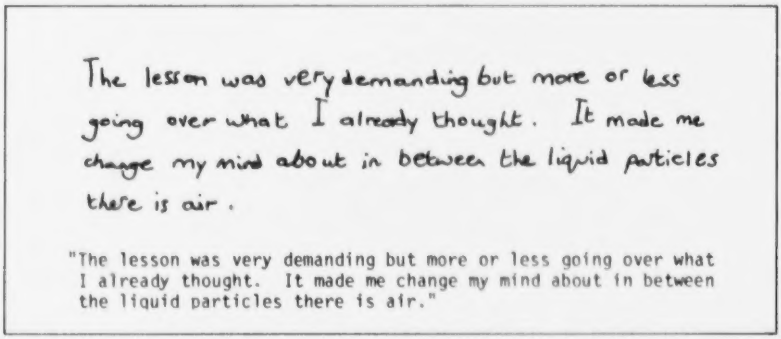
The following extract was taken from Sharon's diary - written during the sequence of lessons on Particulate Theory:



"We started the lesson by finishing off our posters which was interesting again. When all the posters were finished we put them up and somebody from each group read them out. I agreed wholeheartedly with most of the group's conclusion that the space between molecules (or bits) mattered, as to whether the substance behaved in a different way from the others. I didn't agree with Judith's (again) because I don't think that molecules weigh different amounts, just that they are arranged differently in the solid, liquid or gas."

During the restructuring phase, the teacher may make an input to the lessons which is designed to promote conceptual conflict through a surprise demonstration. Alternatively, the teacher may wish to introduce a further piece of evidence which would allow the pupils to extend their ideas. Thus in the Particulate Theory teaching scheme diffusion demonstrations by the teacher would introduce the possibility of particle motion.

Sharon wrote about one such teacher input in her diary:


The lesson was very demanding but more or less going over what I already thought. It made me change my mind about in between the liquid particles there is air.

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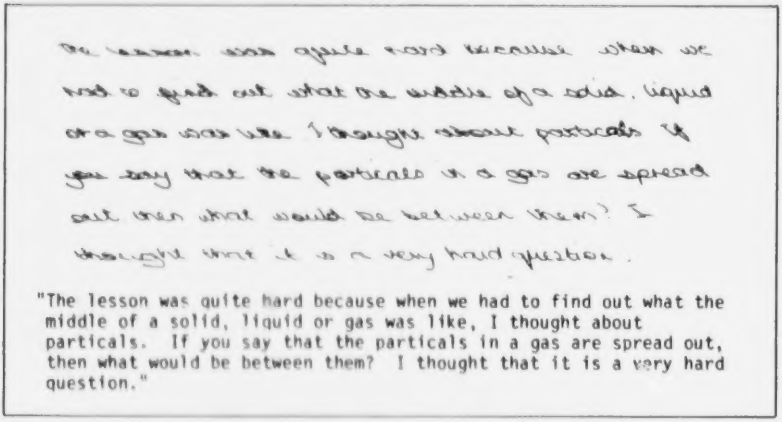
In the application phase, pupils are given the opportunity to use their developing ideas in a variety of situations, both familiar and novel. Thus new concepts may be consolidated and reinforced by extending the contexts within which they are seen to be useful. Application 'tasks' might include further experimental work, creative writing, discussion work and so on. Inevitably, further restructuring of ideas will take place during this phase.

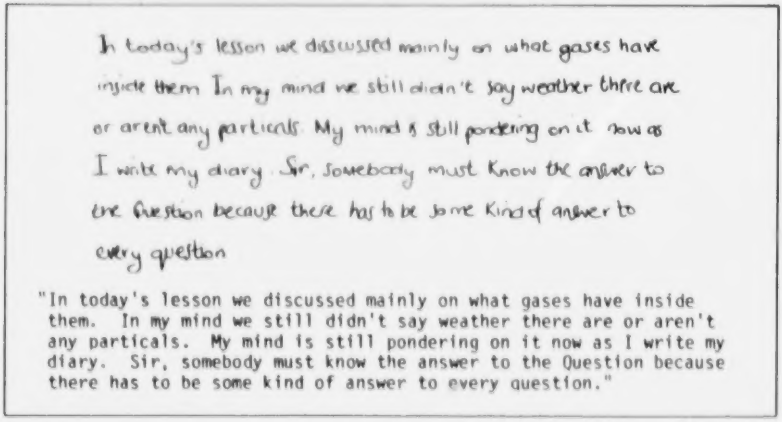
iii) Review of change in ideas

As is indicated by the feedback loop in the teaching sequence diagram (Fig. 2), the pupils are invited to reflect on how their ideas have changed by drawing comparisons between their thinking now and at the start of the unit.

The following extracts indicate that these two pupils were willing, in fact, to reflect upon problematical issues throughout this sequence of lessons:



"The lesson was quite hard because when we had to find out what the middle of a solid, liquid or gas was like, I thought about particals. If you say that the particals in a gas are spread out, then what would be between them? I thought that it is a very hard question."



"In today's lesson we discussed mainly on what gases have inside them. In my mind we still didn't say weather there are or aren't any particals. My mind is still pondering on it now as I write my diary. Sir, somebody must know the answer to the Question because there has to be some kind of answer to every question."

These girls are regarded as being of 'average ability' in an ordinary comprehensive school. Their writing provides clear insight into pupils who are actively involved in developing their ideas. Writing is being used here as a device for further laying bare thoughts and effecting development of new ideas.

2.3 Constructivism – general implications

i) For the teacher

From a constructivist perspective, the role of the teacher is modified. No longer does the teacher play the part of 'purveyor of knowledge'. The teacher's role becomes one of diagnostician, prescriber of appropriate learning activities and facilitator of learning. A naive observer of a traditional science classroom might be forgiven for thinking that the whole exercise was set up for the benefit of the central figure - the teacher. The constructivist classroom sees the teacher as apparently relinquishing this central role in recognition of the principle that learners are responsible for their own learning. Each lesson is organised to promote learning by pupils. Of course, the teacher is still in charge but greater responsibility is given to the pupils.

As a 'diagnostician' and 'prescriber of activities' the teacher is basically setting up an activity, taking note of how the pupils respond to it and then prescribing the next activity in terms of that pupil's response. Thus in the context of the plant nutrition scheme, a group of pupils might be invited to design an experiment to test out one of their ideas relating to how plants feed. The teacher can only decide on what exactly should be done in the next lesson when he/she has seen the pupils' experiments and results. As such, the teacher is in a fluid situation. Activities cannot be planned in isolation and for weeks ahead - although a range of appropriate alternative strategies can be prepared. The dynamic nature of this situation is an inevitable consequence of the way in which pupils learn (which is not by one unit of knowledge per lesson). Initially a teacher may feel more exposed in this new role and less 'in control' of events.

Alongside a new role for the teacher comes the need for revised teaching strategies. Novel teaching strategies bring with them attendant pressures. Consider, for instance, the teacher who is standing at the front of the laboratory, observing discussion groups at work. How is he/she to interpret what is going on? Are the discussion groups gainfully employed? .... or are they wasting their time? Is the noise beyond acceptable levels? Is this an enthusiastic exchange of viewpoints or children talking about last night's TV? What happens if the headteacher pops in? The implementation and management of good group discussion work is certainly demanding of the teacher.

A constructivist approach to teaching inevitably means that the teacher must shift his/her level of focus from whole class to individual pupil more frequently. Importance is attached to the thoughts of each child and various techniques are used to uncover these thoughts. This shift in level of focus will result in the teacher having a more realistic awareness of the precise nature of pupil difficulties. Implications for the teacher have been dealt with briefly here. A more detailed treatment can be found in the second booklet in this series (Needham, 1987).

ii) For the pupil

If the constructivist approach calls for a change of role on the part of the teacher, then we must not ignore the fact that novel demands are also made upon the pupil. An analysis of the Particulate Theory teaching scheme drew attention to the fact that during one lesson the pupils were asked to:

a) develop their own theories

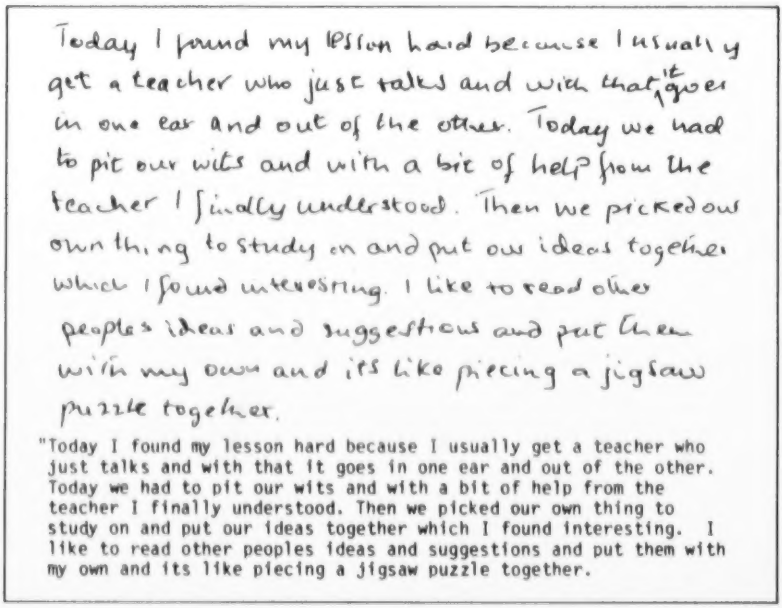
b) compare theories with those of other pupils - via discussion

c) summarise and display their theories - on posters.

Needless to say, not all of the pupils completed these tasks!

The teacher has to be aware not only of the volume of the demands made upon pupils but also of their level of sophistication. How frequently do our pupils get the opportunity to develop their own ideas? How frequently do they have the opportunity to exchange ideas in discussion? Neither of these two activities is easy for the pupil - certainly not so easy as copying from a book. Pupils need plenty of support and direction when they are first introduced to such techniques.

Nevertheless, experience so far, suggests that many pupils have enjoyed the challenge:



Today I found my lesson hard because I usually get a teacher who just talks and with that it goes in one ear and out of the other. Today we had to pit our wits and with a bit of help from the teacher I finally understood. Then we picked our own thing to study on and put our ideas together which I found interesting. I like to read other peoples ideas and suggestions and put them with my own and its like piecing a jigsaw puzzle together.

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iii) For the timing and organisation of the curriculum

Any teaching style which is based upon eliciting pupil ideas and then working from them must, inevitably, be more time consuming than 'transmission methods'. The first reaction of the teacher, new to the constructivist approach, might be simply to state that such longer periods of time cannot be afforded if syllabuses are to be completed. An understandable reaction but on what logic is it based? Are we saying that pupils can successfully work through packed syllabuses to achieve fruitful gains at the end? For the majority this is known not to be the case. So why do we still insist upon setting our pupils off on marathon length endurance courses?

One possible solution to this problem might be found in taking a longer term perspective whilst organising courses within the science department and thereby introducing the pupils to constructivist methods at an early age.

Such an approach would be advantageous from at least two points of view:

a) the ideas introduced by constructivist methods would hopefully be better understood and more meaningful to the pupils

b) the pupils would become familiar with the methodology (gaining confidence in group work; becoming more prepared to reflect upon their own ideas etc.) lower down the school.

Both of these factors would contribute towards easing the problems of shortage of time later on.

In addition, school science departments might consider, in more detail, how the various courses which they offer contribute towards the development of pupils' understanding of some of the major ideas of science - such as ENERGY and MATTER. Very often these ideas are taught over a number of years and within a variety of courses. A teacher at the start of a particular course may not be fully aware of the extent of previous teaching and decide that the best action is to 'start from the beginning again'. A more co-ordinated approach, over successive year groups and across the whole of a science faculty, in planning the development of the 'universal concepts' could pay dividends both in terms of improving pupil learning and reducing wastage of time.

For a more detailed treatment of these curriculum issues refer to the third booklet in this series (Scott and Senior, 1987).

iv) For assessment

Conventional assessment techniques tend to treat pupils' responses as either correct or incorrect, right or wrong. In adopting a constructivist view of learning we recognise that pupils do not simply exchange an incorrect set of ideas for the scientific or correct view. Pupils' ideas tend to develop over a more extended period of time. Assessment techniques are needed which monitor and give credit for the progress a pupil has made. Such information is useful diagnostically to a teacher as well as to the pupil. This is not to suggest that there is no place for formal testing and examining. It is suggesting that a broader range of approaches to assessment may be necessary in order to provide a useful picture, for the teacher, of pupils' progress in understanding. (These techniques may include a wide range of ways of probing pupils' understanding - such as concept maps, card sort tasks, analysing pupils' written work, diagnostic questions.)

3 Concluding remarks

Descriptions of the practical effects of adopting a constructivist view of learning suggest that such a view can have a considerable, and useful, impact upon what happens in the classroom both in terms of teaching and learning.

Constructivism necessarily brings with it a variety of changes in practice for the teacher. At the same time, it should be noted that the teacher is not using novel lesson notes or completely original experiments which unfailingly engage the interest of children. On the contrary, the materials which the teacher works with are largely the same as those used with traditional methods. It is the approach to the teaching which differs and it is an approach which is informed by this view of learning.

Secondary schooling should be a most exciting, stimulating and challenging experience for all of those involved - both pupils and teachers. All too often this is not the case. The adoption of a constructivist view of learning will not, at a stroke, solve the teacher's (and pupil's) problems, but it is likely to foster a more acute awareness, for both teacher and pupil, of the nature of their involvement in the teaching and learning processes.

A recent conversation held between four secondary school science teachers of more than 40 years' total experience and who had all been involved in preparing and teaching constructivist schemes, provides some interesting comments:

> "Constructivism has transformed my view of the classroom."
>
> "It is remarkable to see what ideas the kids have and how they can think through ideas, if given the opportunity."
>
> "I've started thinking about my teaching."
>
> "I see the pupils in a completely different light. For the first time I'm really challenging them and not just going through the motions."

Perhaps the final word, though, should rest with a pupil - Sheila, writing in her diary at the end of a constructivist scheme:

> "Overall I think I enjoyed this new style of teaching. I suppose this course of lessons has made me more confident to put forward my ideas.
> I also feel subconsciously that I have learnt more. The lessons have been approached in a different way and I prefer this way because I don't think that I could have walked out of previous classes and looked 'happy'!
> We were able to think more for ourselves and we were able to put forward our ideas and each ideas was discussed. If I had a choice of which lesson to do - it would be the recent ones."
>
> Sheila 12/12/86

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CLISP Teaching Materials:
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See also the CLISP Summary Booklets relating to students' understanding of:

Elementary ideas in chemistry
Energy
Heat
Particles
Plant Nutrition

The Children's Learning in Science Project

The Children's Learning in Science Project was funded throughout this phase of its work (1984-1986) by the Department of Education and Science and the School Curriculum Development Committee through the Secondary Science Curriculum Review.

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